EFFECTS OF PRESCRIBED FIRE ON PONDEROSA PINE GROWTH

A Final Report to the California Department of Forestry

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Effects of Prescribed Fire on Ponderosa Pine Growth

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PROBLEM

There is insufficient knowledge on patterns of growth in ponderosa pine after prescribed burning. Resource managers and landowners need better information on postfire growth in order to make decisions about the use of fire for silvicultural objectives and hazard reduction.

OBJECTIVES

1. Determine if prescribed burning can be used to improve the growth of ponderosa pine in stands with dense understories.

2. Develop recommendations for the use of prescribed burning as a silvicultural tool in ponderosa pine stands in California

METHODS AND ANALYSIS

The study sites are located at Boggs Mountain State Forest near Cobb, California. Two large plots were established in areas dominated by ponderosa pine forest. One of these plots was designated as a treatment unit on which a prescribed burn was conducted, the other as a control.

Fuel characteristics of litter and duff were recorded on the plots on March 26-27, 1986. Standing dead trees were tagged in order to avoid attributing their death to fire. A prescribed burn was conducted in cooperation with CDF personnel on March 27, 1986. The fire was ignited at 1015 using strip-burning, and active burning ended at 1330. Rates of spread were recorded, as well as flame heights.

Fuel characteristics were again measured after the fire to determine the amount of litter and duff consumed. Data on tree damage were collected the day after the fire for all ponderosa pines $\geq$ 10 cm dbh on the burned plot. The following parameters were measured for 157 ponderosa pines: dbh (cm), volume crown scorch (%), bole scorch height (m), circumference of bole scorched at base (%), depth of bark char upslope and downslope (cm), bark thickness upslope and downslope (cm). Bark char and bark thickness were measured at 20 cm above the soil surface.

Tree mortality will be determined in spring 1987 after budbreak and again in spring 1988. A competition index that includes measurement of diameter and distance to adjacent trees will be used to measure the reduction in competition with tagged overstory trees. Other observations such as level of bark beetle activity will be also be recorded.

Postfire tree growth will be measured in late autumn 1988. Two tree cores will be extracted from each living tree, and 25 trees will be cored on the adjacent unburned plot. These cores will be returned to the lab, dried, mounted in wood blocks, and sanded until individual tracheids are visible.

Ring widths of tree cores will be measured with a microscope/video display system and a Henson incremental measuring machine interfaced with an APPLE II microcomputer. Ring widths will be measured to the nearest 0.01 mm. All cores will be crossdated with a standard chronology prior to statistical analysis.

Ring width measurements will be standardized by fitting ring width series from each core with a cubic spline regression curve. Index values are calculated as the ratio of actual ring width to curve-fitted ring width. Series of index values are then used in subsequent analyses.

Treatments will be compared to controls in order to determine if there has been any departure from expected growth in burned trees. The nature of the variance in the treatment series will be closely examined to determine if there has been any change in the nature of residual patterns or autoregression. Regression analysis will be used to determine the effect on variance in postfire growth caused by fire-induced changes in the vicinity of each tree (e.g., scorch, fuel reduction, thinning). The effect of climatic factors such as temperature and precipitation will also be considered in the analysis.

The two-year analysis will assess only short term response to fire. The study plots and living, burned trees will hopefully be monitored as part of a long term study to evaluate the effect of fire on tree growth.

Tree cores have also been obtained from Cobb Mountain adjacent to Boggs Mountain State Forest. Because ponderosa pines at this site are very old and located on steep slopes, they should provide a long history of tree growth in the area as well as sensitivity to climatic variation. A chronology from this site should be useful for crossdating cores from the Boggs Mountain trees, which generally are less than 80 years old.

RESULTS AND DISCUSSION

The prescribed burn was successfully conducted on the treatment plot on March 27, 1986. The fire was burned in strips because it would not back down fast enough to carry through low fuels. Fuel moistures were: 1 hr - 8-9%, 10 hr - 10-11%, 100 hr - >28%. The initial rate of spread was only 0.1 m/min (at 1015). This increased to 0.3 m/min at 1100. Rate of spread increased as air temperature increased and convection currents developed. Rates as high as 4 m/min were measured at 1220.

Needles in the litter layer carried the fire in most areas, although some 1 hr and 10 hr fuels burned as well. Most fuels on or near the ground were actively involved in the fire, including live shrub fuels. There was little crown fire, except in trees surrounded by brush or slash piles. Flame heights were <50 cm in needles, 50-75 cm in needles and light slash, and >100 cm in heavy slash. There was a 65% (6.3 cm) reduction by depth and 63% (5.2 kg/m^2) reduction by weight in fuels (litter + duff).

Most tree seedlings and small saplings were heavily damaged. Shrub damage appeared to be heavy in both manzanita and coffeeberry. There was some crown scorch in ponderosa pine although most of it was from convective heating rather than from active burning. Most buds were still in a dormant condition at the time of the fire and were probably not seriously damaged. Residual burning of large fuels at the base of trees may have caused some local damage.

Mean diameter of the trees tagged on the treatment plot was 18.9 cm. Mean volume crown scorch was 28%, mean basal scorch was 74%, and mean bole scorch height was 1.4 m. Some of the most important data for the treatment plot remains to be collected. Tree mortality will be evaluated in 1987, and cores will be taken in late 1988. These data will be critical in determining the effects of the prescribed burn on mortality and growth of ponderosa pine.

The chronology for the Cobb Mountain site has been completed and documented in a previously submitted report to CDF (Peterson and Davenport, "Tree Growth Patterns at Cobb Mountain"). This chronology extended back to 1683. High growth peaks were generally more prominent in the chronology than low peaks. Regression analysis indicated that precipitation and temperature variables accounted for only 17% of the variance in tree growth, although spring precipitation and temperature were both significant and positively correlated with growth index.

CONCLUSIONS

Only preliminary conclusions can be offered at this time because critical objectives of the study still need to be completed. The prescribed burn conducted on the treatment plot appeared to be quite successful because it carried well through existing fuels and removed a substantial portion of them. In addition, there appeared to be considerable damage to understory shrubs. Objectives of hazard reduction and removal of competing vegetation were therefore met. The burn demonstrated that a prescribed fire can be conducted to achieve both of these objectives with only a moderate amount of preparation and monitoring. Careful evaluation of fuel moistures and weather conditions contributed greatly to the success of the burn. Underburning in the spring appears to be quite feasible if fuel moistures and weather are appropriate.

The effect of the fire on ponderosa pine mortality and growth will be measured during the next two years. The effect of the fire on all size classes of ponderosa pine is of great interest. Many areas of the treatment plot were overstocked, so some thinning of smaller trees would be desirable. Little outright mortality of overstory trees is expected because crown scorch was generally low, and ponderosa pine bark is generally thick enough to prevent extensive cambial damage.

Several factors can affect the future growth at the treatment site. Crown scorch from the fire clearly reduces photosynthetic production of surviving trees at least temporarily. Damage to the cambium at the base of trees can reduce the transport of water, nutrients, and sugars. Removal of competing shrubs and small trees may increase the amount of resources available to surviving trees, however. In addition, there is normally a period of increased nutrient availability in the soil after fire. Superimposed on this range of factors is the interannual variability in precipitation and temperature. The effect of climate will be carefully evaluated in our analysis of long term growth. Long term (5-10 years) monitoring of surviving trees would be desirable in order to differentiate between short and long term response of trees to the fire treatment. This would also assist in determining long term survival patterns.

TREE GROWTH PATTERNS AT COBB MOUNTAIN

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The California Department of Forestry and the USDA Forest Service are currently investigating the effects of prescribed burning on ponderosa pine stands at Boggs Mountain State Forest in Lake County, California. A major aspect of this study is to determine the effect on tree growth after the fire treatment.

The Boggs Mountain research site is a relatively dense stand on slopes less than 20 percent. This type of site is not normally considered a "sensitive" site for the analysis of tree rings, that is not much contrast would be expected between large and small rings. Trees on steep slopes and shallow soils are generally more subject to moisture stress and therefore have greater sensitivity. Dense stands have competitive interactions among trees that can introduce variability into the general pattern of tree growth at a site. Lack of sensitivity can make it difficult crossdate trees, that is associate each annual ring width increment with a specific calendar year.

The Cobb Mountain area is a potentially more sensitive site for establishing a ring width chronology for the Boggs Mountain study. This area includes a site that has steep slopes on a southwest aspect containing a low density stand of ponderosa pine. This type of site is normally considered ideal for establishing a chronology. The development of a chronology for nearby Cobb Mountain should make it easier to identify growth patterns at Boggs Mountain and allow for more accurate crossdating. In addition, it should provide information on long term tree growth patterns and climate/growth relationships for the Lake County area.

Trees were sampled at Cobb Mountain in August, 1985. The sampling site was at approximately 1500 m elevation, on a southwest-facing aspect, with slopes of 30-40%. Ponderosa pine was the dominant species at the site, with some sugar pine and Douglas-fir. There was a relatively low density of overstory trees. Manzanita and live oak were present in the understory (Fig. 1). Soils were moderately deep and gravelly and derived from volcanic parent material.

Ponderosa pine was the only species sampled. Trees were sampled from east to west along the southwest aspect. The diameter of each sample tree was recorded and any physical defects noted. Most of the trees at this site have broken or disfigured tops caused by wind damage (Fig. 2). Trees with large fire scars were not included in the sample.

Two cores were extracted from each tree at 1.3 m above the ground using an increment borer. Cores were stored in straws and returned to the laboratory. Cores were dried, mounted in wood blocks, and sanded with progressively finer grades of sandpaper until individual xylem cells were clearly visible.

Each core was examined to determine if it could be accurately crossdated. There were a large number of apparent disruptions in growth patterns of the trees at Cobb Mountain, presumably because of the periodic wind damage to the crowns. Nevertheless, most of the cores could be crossdated, and cores from 17 trees were retained for analysis. Diameters of sample trees ranged from 20.8 to 92.0 cm with a mean of 67.7 cm.

The range of years included in each ring width series is summarized in Table 1. The oldest tree sampled was dated back to 1683. Ring width data were converted to growth index values by standardization. This procedure removes the effect of age from the series and makes the series variance homogeneous. Trees of different ages and sizes can therefore be included in the same analysis of relative growth. Standardization is accomplished by fitting each ring width series with a regression curve, then calculating growth index as the ratio of actual growth to estimated (curve-fitted) growth. Growth index therefore has a mean value of approximately 1.0 for a given series.

Data were aggregated for all trees after standardization. The mean values of growth index for Cobb Mountain are listed in Table 2 and displayed in Fig. 3. The best growth years for the 302-year series were 1710, 1744, 1816, and 1906. Growth since 1980 also shows a general upward trend. Low growth peaks are not as prominent ~~h~~as high growth peaks throughout the series. A prominent peak normally has one or more years of high (in the case of high peaks) or low (in the case of low peaks) growth adjacent to it, which suggests that there is some year to year correlation in growth. This is also supported by the moderately high autocorrelation value in Table 2.

Climate is generally the factor most closely associated with tree growth. The relationship between climate and tree growth was examined by regressing tree growth against records of precipitation and temperature. Monthly values for total precipitation and mean temperature were compiled for the St. Helena weather station from National Oceanic and Atmospheric Administration records (since 1914). Total precipitation and mean temperature were aggregated into three seasons: winter (October through March), spring (April through June), and summer (July through September).

Regression analysis indicated that the regression model was significant although it could account for only 17% of the overall variance in tree growth (Table 3). Spring precipitation and spring temperature were the most important variables related to tree growth and accounted for 40% and 33% of the model variance respectively. Both of these variables were positively correlated with tree growth. Greater spring precipitation may improve soil moisture status during the rapid spring growth period and provide moisture reserves through the early part of the dry summer months. Warmer spring temperatures may encourage early release from dormancy and allow for a longer growing season and therefore greater wood production.

The growth patterns of ponderosa pine at Cobb Mountain are correlated rather well with other chronologies of tree growth from the Mendocino National Forest, which suggests that these areas are affected by similar weather patterns. The Cobb Mountain tree growth patterns are quite different from chronologies we have developed for the south-central Sierra Nevada, which is subject to different climatic influences. The availability of a long record of tree growth at Cobb Mountain will provide a valuable perspective for crossdating and evaluating growth patterns in studies of tree growth at Boggs Mountain State Forest or other sites in the Lake County area.

Table 1. Diameter and range of dates for ponderosa pine cores collected at Cobb Mountain. Some trees may be older than indicated (*) because not all trees could be cored to the center.

Tree core number	Diameter (cm)	Range of dates
*CM1E	90.5	1790-1984
*CM2E	89.9	1811-1984
CM3E	58.2	1808-1984
CM4E	64.8	1755-1984
*CM5E	79.0	1763-1984
CM7E	63.7	1742-1984
CM8E	20.8	1931-1984
CM10E	41.6	1852-1984
CM11E	73.7	1855-1984
CM12E	84.8	1781-1984
CM13W	40.0	1841-1984
CM14W	50.3	1864-1984
*CM15W	71.5	1724-1984
*CM16E	81.8	1683-1984
*CM17E	92.0	1716-1984
CM18W	63.5	1756-1984
CM19S	61.8	1707-1984

2. Summary of growth index values by year for ponderosa [illegible]
The number of series used to calculate each index value are given on the right side of the table. Summary statistics are listed at the bottom.

RUN TITLE COBB MOUNTAIN
DATE RUN

IDENT. SUMMARY OF TREE-RING INDICES SEQ. PG.
CM1PPX 18 1

SEQUENCE NUMBERS INCLUDED ARE 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17

	INDICES										NUMBER OF SERIES									
YEAR	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9
1683				1.279	1.302	0.547	0.636	1.075	0.768	1.132				1.	1.	1.	1.	1.	1.	1.
1690	0.627	0.429	1.157	0.761	1.126	0.950	1.228	0.952	1.163	0.843	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.
1700	0.744	0.589	0.812	1.180	1.059	0.881	1.005	1.146	1.132	1.375	1.	1.	1.	1.	1.	1.	1.	2.	2.	2.
1710	1.871	1.567	1.773	1.189	0.987	1.003	1.320	1.188	0.731	0.796	2.	2.	2.	2.	2.	2.	3.	3.	3.	3.
1720	0.958	0.675	0.822	0.800	1.162	0.782	0.707	0.723	0.927	1.106	3.	3.	3.	3.	4.	4.	4.	4.	4.	4.
1730	1.143	1.145	0.879	0.629	0.723	1.037	1.135	0.825	0.610	0.665	4.	4.	4.	4.	4.	4.	4.	4.	4.	4.
1740	0.833	0.505	1.449	1.500	1.645	1.261	1.512	1.074	0.764	0.846	4.	4.	5.	5.	5.	5.	5.	5.	5.	5.
1750	0.753	0.775	0.839	1.146	1.080	1.513	1.068	1.083	1.383	1.423	5.	5.	5.	5.	5.	6.	7.	7.	7.	7.
1760	0.857	0.805	1.105	1.072	1.027	1.088	1.108	0.864	0.730	0.874	7.	7.	7.	8.	8.	8.	8.	8.	8.	8.
1770	0.916	0.586	0.784	0.959	0.953	1.060	0.803	1.041	0.779	0.798	8.	8.	8.	8.	8.	8.	8.	8.	8.	8.
1780	0.967	1.025	0.951	0.814	1.072	1.024	0.952	0.746	0.798	0.987	8.	9.	9.	9.	9.	9.	9.	9.	9.	9.
1790	0.874	0.764	1.070	1.174	1.171	0.919	1.267	0.833	0.858	1.170	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.
1800	0.965	0.777	0.855	0.962	0.967	0.718	0.731	0.743	0.832	0.945	10.	10.	10.	10.	10.	10.	10.	10.	11.	11.
1810	1.018	0.803	0.901	1.111	1.032	1.111	1.734	1.194	1.330	1.009	11.	12.	12.	12.	12.	12.	12.	12.	12.	12.
1820	1.143	0.999	1.084	1.045	1.179	1.044	0.980	1.152	1.165	0.995	12.	12.	12.	12.	12.	12.	12.	12.	12.	12.
1830	1.015	0.758	0.875	0.957	0.524	1.013	1.281	1.208	0.894	0.878	12.	12.	12.	12.	12.	12.	12.	12.	12.	12.
1840	1.101	1.306	1.089	1.161	1.075	1.338	1.275	0.955	0.941	0.729	12.	13.	13.	13.	13.	13.	13.	13.	13.	13.
1850	0.886	0.726	0.973	0.947	1.031	1.058	1.154	1.111	0.985	0.926	13.	13.	14.	14.	14.	15.	15.	15.	15.	15.
1860	0.893	0.737	0.713	0.895	0.981	0.970	1.289	0.847	0.865	0.873	15.	15.	15.	15.	16.	16.	16.	16.	16.	16.
1870	0.994	0.676	1.024	0.702	0.935	1.025	0.819	0.921	0.942	1.129	16.	16.	16.	16.	16.	16.	16.	16.	16.	16.
1880	0.941	0.878	1.148	1.059	0.958	1.071	1.311	1.045	1.044	1.237	16.	16.	16.	16.	16.	16.	16.	16.	16.	16.
1890	0.952	0.565	1.011	0.815	0.900	0.780	1.301	0.927	0.893	1.103	16.	16.	16.	16.	16.	16.	16.	16.	16.	16.
1900	1.156	0.635	1.200	1.213	1.052	1.417	1.866	1.151	0.861	0.975	16.	16.	16.	16.	16.	16.	16.	16.	16.	16.
1910	0.794	0.606	0.700	0.869	0.936	1.098	1.492	0.984	0.999	1.032	16.	16.	16.	16.	16.	16.	16.	16.	16.	16.
1920	0.998	0.648	0.751	1.036	0.847	0.824	1.326	1.053	1.140	0.935	16.	16.	16.	16.	16.	16.	16.	16.	16.	16.
1930	0.554	0.864	1.240	0.955	1.411	0.930	1.277	0.967	1.086	0.878	16.	17.	17.	17.	17.	17.	17.	17.	17.	17.
1940	0.699	0.824	1.067	1.189	0.977	1.050	0.998	0.963	1.123	0.758	17.	17.	17.	17.	17.	17.	17.	17.	17.	17.
1950	0.673	0.874	0.768	0.990	1.102	1.199	1.060	0.968	1.363	0.903	17.	17.	17.	17.	17.	17.	17.	17.	17.	17.
1960	1.140	0.726	1.156	1.303	1.301	1.042	1.286	0.779	0.879	0.838	17.	17.	17.	17.	17.	17.	17.	17.	17.	17.
1970	0.728	0.955	0.850	0.792	0.936	0.749	1.192	0.889	0.917	1.062	17.	17.	17.	17.	17.	17.	17.	17.	17.	17.
1980	1.310	0.854	1.051	0.971	1.515						17.	17.	17.	17.	17.					

*** STATISTICS FOR SUMMARY ***

TIME RANGE IS	1683-1984	NUMBER OF YEARS	302	STANDARD DEVIATION	0.229
FIRST ORDER AUTOCORRELATION	0.371	MEAN SENSITIVITY	0.204	MEAN INDEX VALUE	0.995
STANDARD ERROR	0.149	SUM OF INDICES	300.371	SUM OF SQ. OF INDICES	314.573

Table 3. Summary of regression statistics for climatic variables regressed against growth index of ponderosa pine at Cobb Mountain.

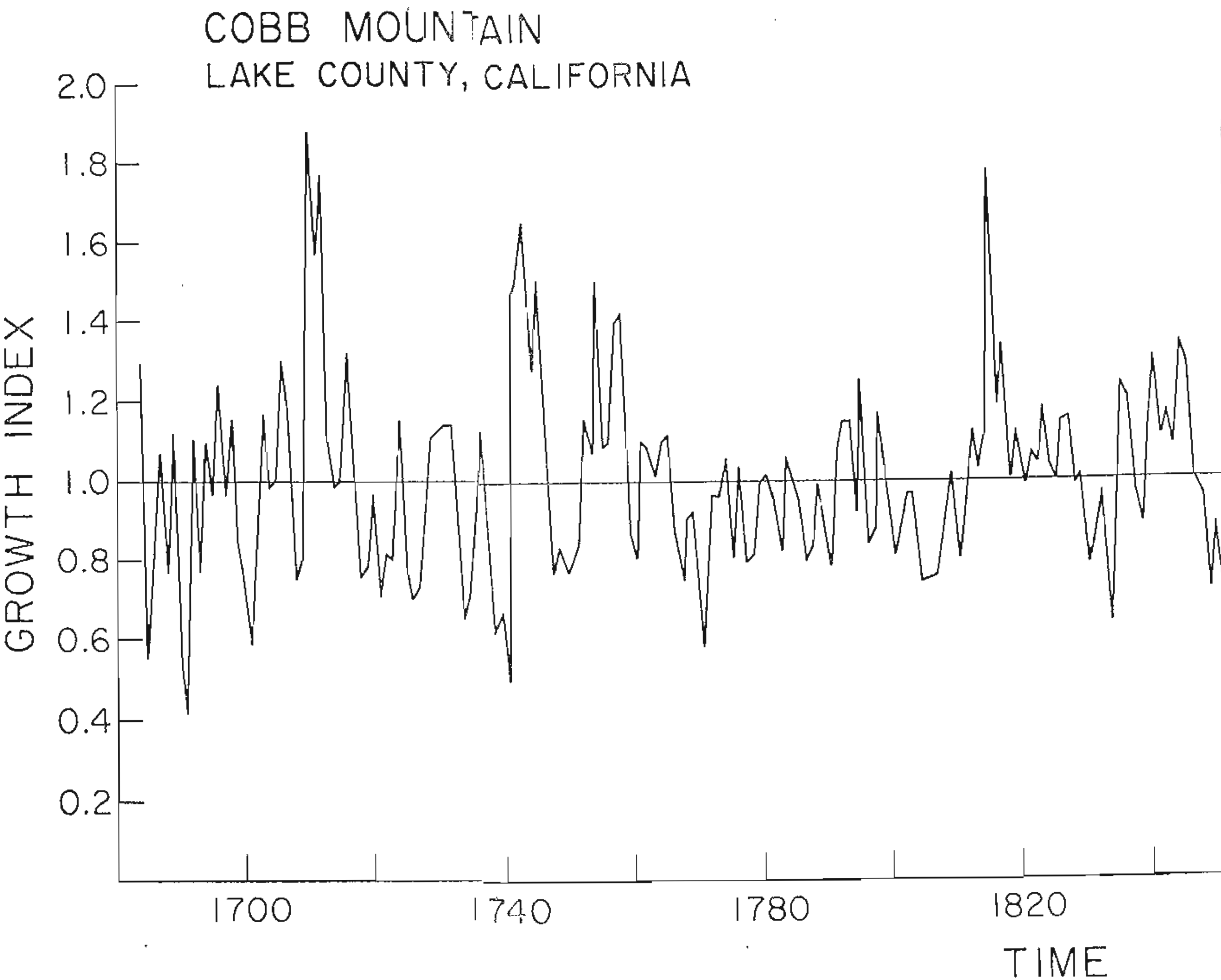
Source	Degrees of freedom	Sum of squares	F value	Probability > F
Model	6	0.503	2.16	0.06
Error	64	2.483		
Total	70	2.987		
Winter precipitation	1	0.024	0.62	0.43
Spring precipitation	1	0.268	6.90	0.01
Summer precipitation	1	0.037	0.96	0.33
Winter temperature	1	0.082	2.11	0.15
Spring temperature	1	0.221	5.71	0.02
Summer temperature	1	0.043	1.11	0.29

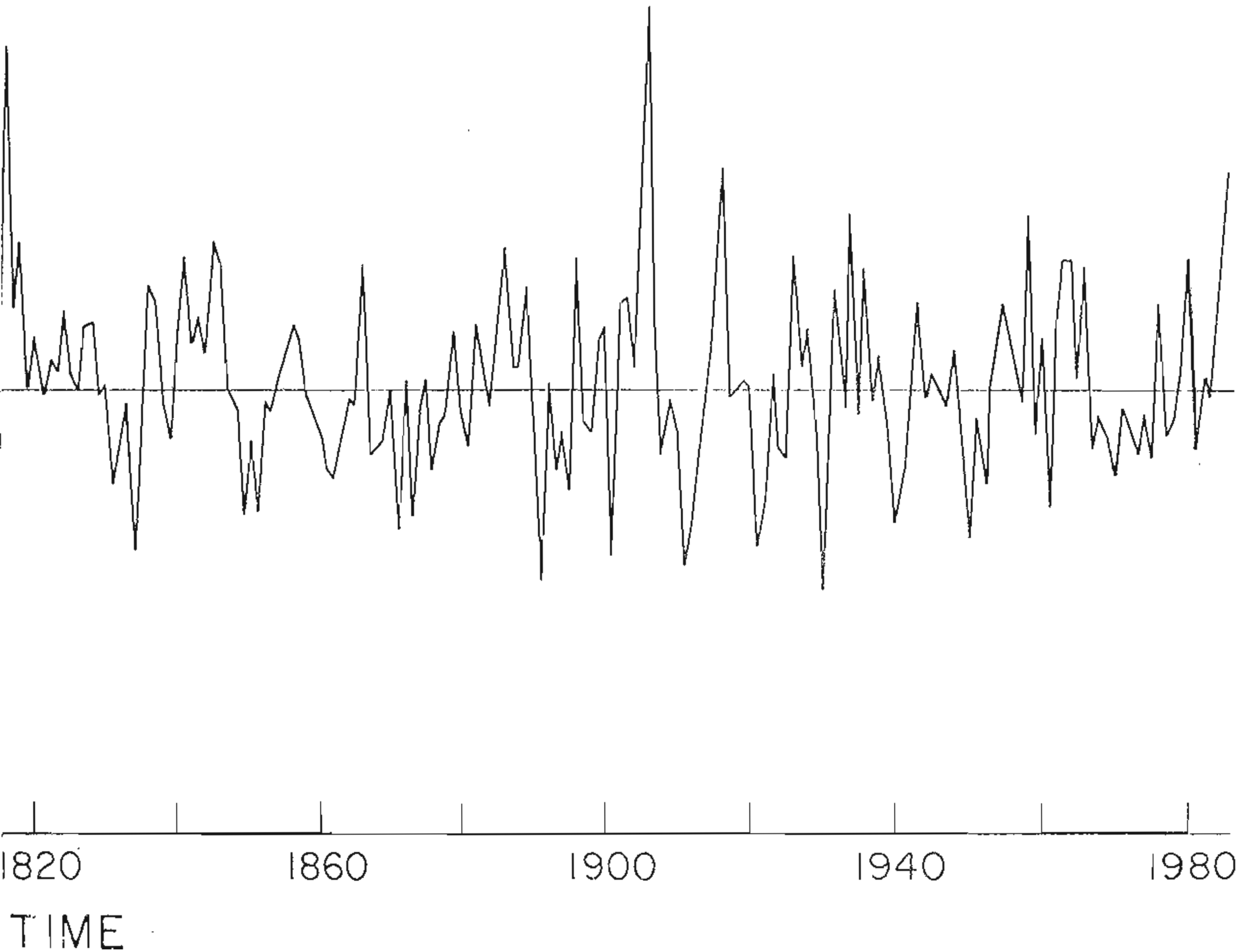
Variable	Estimate (coefficient value)	t value*	Probability > t
Intercept	-3.739	-2.50	0.02
Winter precipitation	-0.011	-0.79	0.43
Spring precipitation	0.089	2.63	0.01
Summer precipitation	-0.089	-0.98	0.33
Winter temperature	0.025	1.45	0.15
Spring temperature	0.038	2.39	0.02
Summer temperature	0.016	1.06	0.30

* t value tests null hypothesis that coefficient of variable = 0

FIGURE 1. Typical sampling area at Cobb Mountain. Ponderosa pine dominates the overstory on a southwest aspect with moderately steep slopes.

FIGURE 2. The irregular crown shape of this ponderosa pine is typical of many of the larger trees at Cobb Mountain. Exosure to wind at this site causes breakage in the upper part of the bole, resulting in disfigured upper crowns and disruptions in growth patterns.


COBB MOUNTAIN
LAKE COUNTY, CALIFORNIA
GROWTH INDEX
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
1700
1740
1780
1820
TIME


1820
1860
1900
1940
1980
TIME